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SNS DTL1-3 Fault Study Plan

This document details the fault study plan for DTL1-3 during the commissioning phase planned for April 2004. The studies are limited to unchopped beam. The layout of the facility is given in section 1. The outline of the fault study plan is laid out in section 2, including the goals and a general method for achieving them. Section 3 is a more detailed plan, each subsection viewed as a plan for each fault outlined in section 2.

1 Layout

Figure 1 shows the top view layout of the FE-DTL1-3 beam line, including part of the enclosure for DTL1-3 along with the labyrinth leading from it to the Front End (FE) control room and the cable and waveguide penetrations leading to outside the enclosure. Figure 2 shows the entire enclosure for DTL1-3.
The FE-DTL1-3 area may be divided into three zones: Zone 1 covers the FE control room and the FE portion of the beam line (i.e. Ion source, LEBT, RFQ and MEBT). Zone 2 covers the DTL1-3 enclosure, including the labyrinth to it from the FE control room. Zone 3 is the linac tunnel downstream of the DTL1-3 enclosure (see figures 1 and 2).

2 Fault Study Plan

2.1 Goals

The fault study goals are:

(a) Establish routine dose rates outside shielding
(b) Measure the dose at various points outside the DTL1-3 enclosure area while controlled faults are occurring, in order to determine the optimal location of interlocked area radiation monitors (Chipmunks), the attenuation achieved by radiation shielding and the labyrinth, and the maximum fault dose rates at all penetrations
(c) Estimate the quality factor of neutrons to be used to set the Chipmunks.
(d) Measure beam transmission to the beam stop while controlled faults are occurring in order to assess the accuracy of beam transmission predictions under abnormal conditions.

2.2 Method

(a) Routine dose rates:

1. For an initial nominal beam going into the MEBT beam stop, record all chipmunk readings and check dose rates near this beam stop.
2. Accelerate the beam up to 7.5 MeV and transport it into the EDFC1 , record all chipmunk readings and check doses in the locations i.-vi. as marked below and check dose rates near this beam stop with remote readout.
3. Accelerate the beam up to 23 MeV and transport it into the EDFC2, record all chipmunk readings and check doses in the locations i.-vi. as marked below and check dose rates near this beam stop with remote readout.
4. Accelerate the beam up to 40 MeV and transport it into the EDFC3, record all chipmunk readings and check doses in the locations i.-vi. as marked below and check dose rates near this beam stop with remote readout.
5. Accelerate the beam up to 40 MeV and transport it into the beam stop, record all chipmunk readings and check doses in the locations i.-vi. as marked below and check dose rates near this beam stop with remote readout.

(i) at the shield wall west of the DTL1-3 enclosure;
(ii) outside the North wall of the labyrinth;
(iii) in the linac tunnel downstream of the DTL1-3 enclosure;
(iv) near the penetrations south of the DTL1-3 enclosure;

(v) in the Klystron building near the DTL3-4 penetrations;
(vi) on the mezzanine near the alignment penetration.

Note that for later studies (e.g. at different repetition rates and pulse lengths), dose rate estimates may be obtained by scaling these measurements.

(b) Create the 4 faults listed below and check doses in corresponding locations:

1. Beam of 2.5 – 40MeV on drift tubes of DTL1-3 by switching off MEBT quad#13. Survey near this quad and the upstream DTLs ,record all chipmunk readings and the current to the beamstop.
2. Beam of 2.5 – 40MeV on drift tubes of DTL1-3 by switching off MEBT quad#14. Survey near this quad and the upstream DTLs ,record all chipmunk readings and the current to the beamstop.
3. Beam of ~7.5 MeV on the drift tubes of DTL2,3 by switching off the RF of DTL tank 2. Survey at locations as listed under 2.2 (a) , record all chipmunk readings and the current to the beamstop. Survey near the end of the DTL2 tank and the DTL3 using remote read-out.
4. Beam of ~22 MeV on the drift tubes of DTL3 by switching off the RF of DTL tank 3. Survey at locations as listed under 2.2 (a) ,record all chipmunk readings and the current to the beamstop. Survey near the end of the DTL3 tank using remote read-out.

(c) Each of the (non-automated) radiation measurements described above will be carried out by an RCT using approved, calibrated instrumentation capable of detecting neutrons and photons. Instruments approved for measurements of this type at ORNL include a Remball with integrating electronics and/or an analog Snoopy for neutrons, and an RO-20 for photons. All of these instruments have been shown (by comparison with TLDs and the Health Physics Instrument model HPI1030) to have acceptable accuracy in the pulsed fields found at SNS. In addition, the ORNL-approved Bicron Microrem will be compared to other instruments to confirm that it is accurate in the pulsed fields found at SNS. The REM500 neutron spectrometer will be used to directly measure quality factors any time the neutron flux in an occupied area is sufficient for use of that instrument. A more elaborate set various-sized Bonner spheres is available for neutron spectroscopy measurements if the neutron dose rate in an occupied area is sufficient and stable. A Chipmunk and a commercial version of the Chipmunk radiation monitor will be used to monitor radiation fields inside the DTL1-3 enclosure – both have been shown to compare favorably with HPI1030 measurements in the pulsed fields found at SNS.

2.3 Chipmunks Locations

A total of five chipmunks are currently positioned in the following locations (see figure 3):

- Between Ion Source and FE control room (#100).
- Just north of the MEBT (#101).
- South of the DTL1-3 shield wall (#102).
- Just east of the downstream PPS gate (#103).
- Up in the mezzanine above the DTL1-3 enclosure (#105).

3 Fault Studies Step-By-Step

In this section the different fault studies are detailed one by one. The expected dose rates, in mrem/hour, at various key locations are listed for each fault mode. Some other faults were considered but didn't qualify for fault study because resulting beam losses are insignificant or loss pattern is similar to the scenarios in the plan (e.g. with MEBT steerers, which according to simulations cause beam loss of less than 4% in the DTL1-DTL2-DTL3 enclosure). All fault studies will be conducted under MPS protection. Fault studies other than those found in this chapter will be prompted if needed, as set out in SNS-OPM 2.H-16 (Fault Study Procedure for Primary and Secondary Beam Areas). Expected distribution of lost particles along the beam line used in radiation field calculations is listed in the Appendix.

(a) Routine dose rates:

1. For an initial nominal beam (2.5 MeV, 20 mA, 50 microsec, 1 Hz) going into the MEBT beam stop, record all chipmunk readings and the current to the beamstop,check dose rates near this beam stop.

   Expected dose rate estimates (mrem/hour):

Location	neutron	Gamma
30 cm from beam stop	0.135	0.0025
100 cm from beam stop	0.012	<0.001

2. Accelerate the beam under **3** (a) 1. up to 7.5 MeV and transport it into the EDFC1, record all chipmunk readings and the current to the beamstop, check dose rates in the locations i.-vi. as marked under 2.2 (a). Measure near beam stop using remote readout. Locations L1 through L4 are shown in figure 1.

   Expected dose rate estimates (mrem/hour):

Location (inside enclosure)	Neutron	Gamma
North of beam stop, against poly	0.2	0.5
South of beam stop, against poly	0.2	0.5
Above beam stop, on top of poly	0.2	0.5
L1	0.7	1.8
L2	0.03	0.1
L3	0.01	0.03
L4	0.001	0.004

Expected dose rate estimates (mrem/hour):

Location (outside enclosure)	neutron	Gamma
i.	<0.1	<0.1
ii.	<0.1	<0.1
iii.	<0.1	<0.1
iv.	<0.1	<0.1
v.	<0.1	<0.1
vi.	<0.1	<0.1

3. Accelerate the beam under **3** (a) 1. up to 22 MeV and transport it into the EDFC2, record all chipmunk readings and the current to the beamstop, check dose rates in the locations i.-vi. as marked under 2.2 (a). Measure near beam stop using remote readout. Locations L1 through L4 are shown in figure 1.

Expected dose rate estimates (mrem/hour):

Location (inside enclosure)	Neutron	Gamma
North of beam stop, against poly	40-100	3-8
South of beam stop, against poly	40-100	3-8
Above beam stop, on top of poly	20-60	5
L1	400	50-80
L2	10-20	1-4
L3	15-50	5-20
L4	2	0.2

Expected dose rate estimates (mrem/hour):

Location (outside enclosure)	neutron	Gamma
i.	0.01-0.3	0.8
ii.	0.01-0.13	0.05-0.2
iii.	0.1	0.02
iv.	1-2.5	0.25

v.	<0.01	-
vi.	0.1-1.5	0.2-1.5

4. Accelerate the beam under **3** (a) 1. up to 40 MeV and transport it into the EDFC3, record all chipmunk readings and the current to the beamstop, check dose rates in the locations i.-vi. as marked under 2.2 (a). Measure near beam stop using remote readout. Locations L1 through L4 are shown in figure 1.

Expected dose rate estimates (mrem/hour):

Location (inside enclosure)	Neutron	Gamma
North of beam stop, against poly	1500-3000	200-2000
South of beam stop, against poly	1000-2200	200-2000
Above beam stop, on top of poly	1500-4000	200-2000
L1	150-250	12-20
L2	20	2
L3	3-5	1
L4	0.5	0.1

Expected dose rate estimates (mrem/hour):

Location (outside enclosure)	neutron	Gamma
i.	0.2-1	0.1-0.6
ii.	0.01-0.1	0.01
iii.	1.5	0.25
iv.	0.5-1	0.1-0.25
v.	0.3	-
vi.	0.2-1	0.1-0.4

(b) Using beam under 3 (a) perform the following fault studies:

1. Beam of ~7.5 MeV on the drift tubes of DTL2 by switching off the RF of DTL tank 2. Survey at locations as listed under 2.2 (a), record all chipmunk readings and the current to the beamstop. Survey along DTLs using remote read-out.

Expected dose rate estimates (mrem/hour):

Location (inside enclosure)	Neutron	Gamma
North of beam stop, against poly	1.5-4.	0.3
South of beam stop, against poly	1.5-4.	0.25
Above beam stop, on top of poly	1.5-2.5	0.25
L1	55	1.8
L2	22	0.6
L3	3	0.22
L4	0.45	0.05

Expected dose rate estimates (mrem/hour):

Location (outside enclosure)	neutron	Gamma
i.	<0.01	0.03-0.06
ii.	0.025	0.05
iii.	0.05	0.01
iv.	0.5	0.03
v.	<0.01	<0.01
vi.	0.15	0.1

2. Beam of ~22 MeV on the drift tubes of DTL3 by switching off the RF of DTL tank 3. Survey at locations as listed under 2.2 (a), record all chipmunk readings and the current to the beamstop. Survey along the DTLs using remote read-out.
During this fault study the proton beam (mA, 50 microsec, 1 Hz) is planed to be deposited completely in the copper beam stop at energy about 22 MeV, which is lower than during normal commissioning operation. So, the expected dose rates inside and outside the enclosure will be lower than during the commissioning with 39.8 MeV beam into copper beam stop..

3. Beam of 2.5 – 40MeV on drift tubes of DTL1-3 by switching off MEBT quad#13. Survey near this quad and the upstream DTLs, record all chipmunk readings and the current to the beamstop.
88% of the beam is deposited into beam stop. Deposited beam is at lower power than the commissioning one - at 12 W (about 3 times). The rest of the beam, deposited inside the dtl tanks at energies from 2.5 to 25 MeV does not make significant influence over total dose rate inside and outside the

enclosure. So, the total dose rates will be lower than during normal commissioning into copper beam stop.

4. Beam of 2.5 – 40MeV on drift tubes of DTL1-3 by switching off MEBT quad#14. Survey at locations as listed under 2.2 (a), record all chipmunk readings and the current to the beamstop. Survey along DTLs using remote read-out.

Location (inside enclosure)	Neutron	Gamma
North of beam stop, against poly	30-100	100-180
South of beam stop, against poly	30-100	100-180
Above beam stop, on top of poly	30-100	100-180
L1	3	0.1
L2	0.15	<0.01
L3	0.2	<0.01
L4	<0.01	<0.01

Location (outside enclosure)	neutron	Gamma
i.	0.02	<0.01
ii.	<0.01	<0.01
iii.	0.05	<0.01
iv.	0.05	<0.01
v.	<0.01	<0.01
vi.	<0.01	<0.01

Figure 1 Layout of the FE-DTL1-3 beam line. L1, L2, L3 and L4 are locations for measurements in the labyrinth.

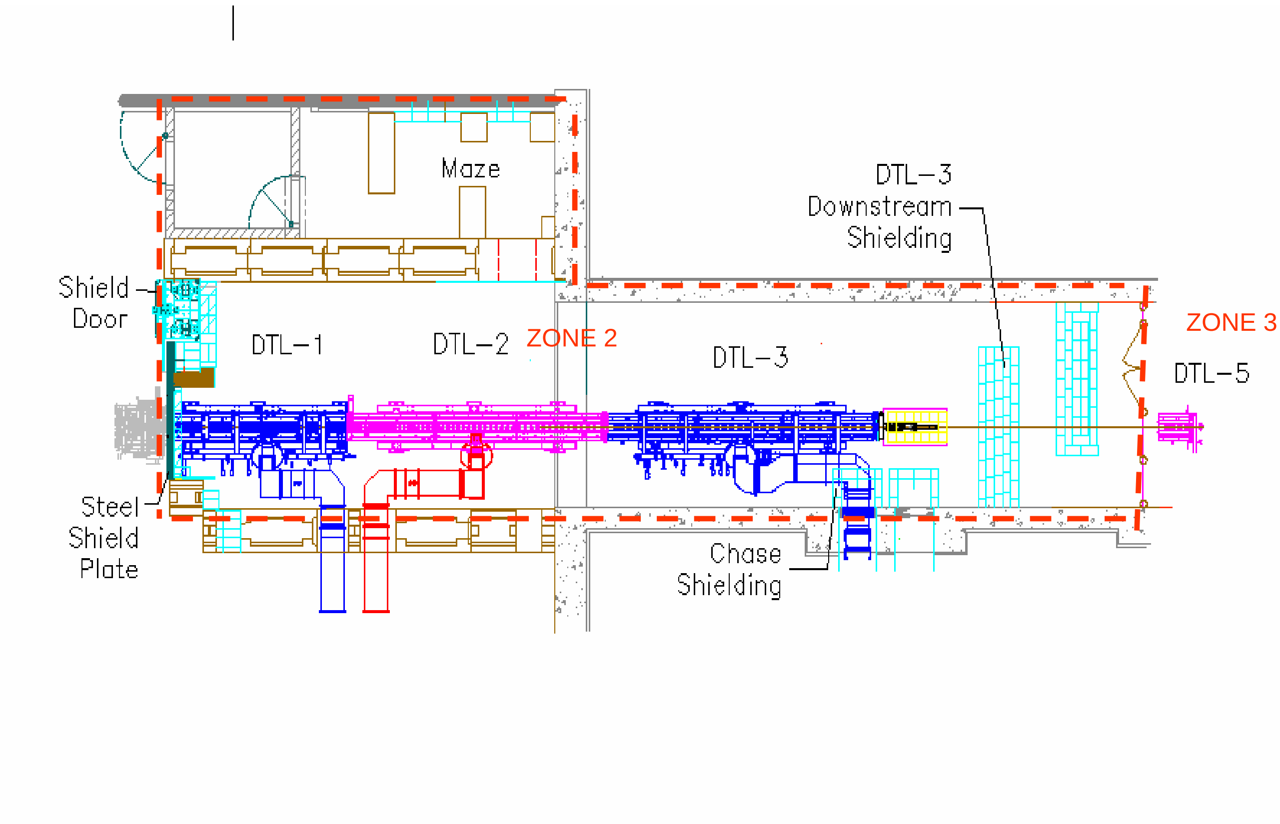

Figure 2 Layout of the enclosure containing the DTL1-3 beam line

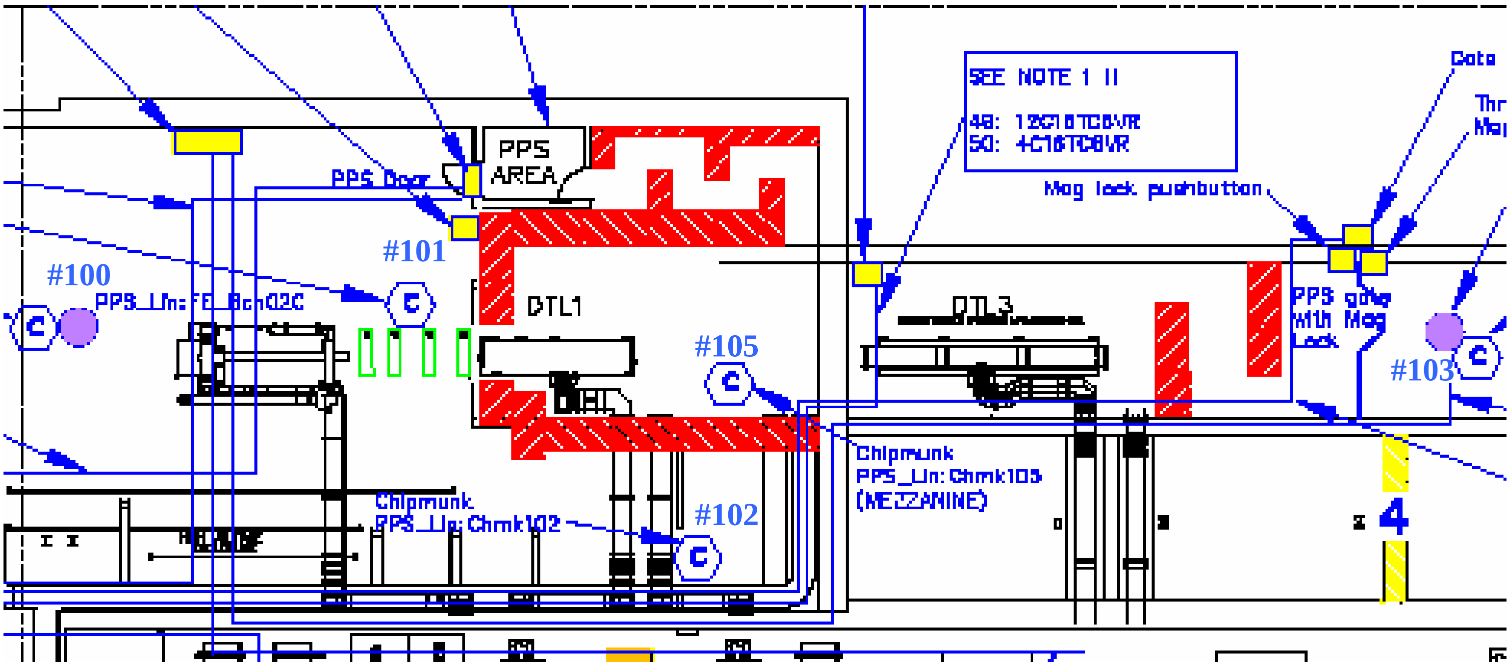

Figure 3 Personnel Protection System (PPS) layout of the FE-DTL1-3 beam line; Chipmunks are marked as . Refer to drawing 109090101-R8C-8100-A082 Rev1 for details.

Appendix.

Distribution of lost particles along the beam line for the fault scenarios #1-4 was calculated using PARMILA particle tracking code. Longitudinal coordinate, energy and deposited power at point of loss is shown in the table below.

z [cm]	Energy [MeV]	Power [W]
fault #1		
3.44E+02	2.50E+00	9.42E-01
3.63E+02	2.50E+00	7.47E-01
3.65E+02	2.50E+00	8.49E-01
3.70E+02	2.53E+00	5.07E-01
4.38E+02	2.90E+00	5.37E-02
4.44E+02	2.94E+00	4.55E-02
5.51E+02	3.88E+00	8.99E-02
5.58E+02	3.96E+00	2.26E-03
6.84E+02	5.69E+00	2.70E-03
7.90E+02	7.52E+00	5.93E-02
7.99E+02	7.71E+00	2.86E-02
1.13E+03	1.57E+01	1.49E-03

2.07E+03	3.98E+01	2.44E+01

fault #2

4.56E+02	3.02E+00	1.18E-02
4.62E+02	3.07E+00	4.37E-03
5.71E+02	4.11E+00	3.55E-02
5.78E+02	4.19E+00	2.79E-03
7.09E+02	6.12E+00	2.39E-02
8.28E+02	8.35E+00	7.93E-04
1.44E+03	2.37E+01	2.25E-03
1.65E+03	2.93E+01	1.39E-02
1.67E+03	2.98E+01	2.83E-03
1.88E+03	3.55E+01	6.74E-03
2.07E+03	3.98E+01	7.48E+01

fault #3

1.21E+03	7.52E+00	2.86E-03
1.24E+03	7.52E+00	3.25E-01
1.26E+03	7.52E+00	1.92E+00
1.29E+03	7.52E+00	4.74E-01
1.30E+03	7.52E+00	2.37E+00
1.32E+03	7.52E+00	3.55E-01
1.33E+03	7.52E+00	3.43E+00
1.35E+03	7.53E+00	1.80E+00
1.36E+03	7.50E+00	4.03E-01
1.38E+03	7.52E+00	1.41E+00
1.41E+03	7.60E+00	3.36E-01
1.41E+03	7.60E+00	5.62E-01
1.43E+03	7.47E+00	4.38E-01
1.44E+03	7.41E+00	1.61E-01
1.46E+03	7.54E+00	8.52E-02
1.48E+03	7.67E+00	1.05E-01
1.49E+03	7.56E+00	4.31E-02
1.51E+03	7.41E+00	2.04E-02
1.53E+03	7.39E+00	2.32E-02
1.55E+03	7.40E+00	9.15E-03
1.56E+03	7.51E+00	1.21E-02

fault #4

2.07E+03	2.29E+01	4.35E+01